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MOVEMENTS, ACTIVITY RANGE, HABITAT USE, AND CONSERVATION OF THE JAMAICAN (YELLOW) BOA, EPICRATES SUBFLAVUS

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MOVEMENTS, ACTIVITY RANGE, HABITAT USE, AND CONSERVATION OF

THE JAMAICAN (YELLOW) BOA, *EPICRATES SUBFLAVUS*

by
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Movements, Activity Ranges, Habitat Use, and Conservation of the Jamaican (Yellow) Boa, *Epicrates subflavus*

Chair: Dr. Christopher Servheen

The endemic Jamaican boa, *Epicrates subflavus*, was once common throughout Jamaica. This vulnerable species is now fragmented into small populations throughout the island due to habitat loss, introduced species, human persecution and poaching. Conservation of the boa requires knowledge of the basic ecology of the boa and education of local people. Jamaican boas were studied in the community of Windsor in Jamaica's Cockpit Country. Radio telemetry was used to examine the movements, activity ranges, and habitat use of twelve boas. In addition, an outreach program was undertaken to combat human persecution and poaching.

Male Jamaican boas moved greater distances per day than females. Home ranges varied in size from 2.24 – 14.03ha for 95% MCPs for all boas with male home ranges and core activity areas being larger than those of females. Vine and epiphyte coverage of trees and tree DBH are key features of boa habitats. Vines and epiphytes provide resting places, camouflage, and travel routes for boas.

Conservation of the Jamaican boa must include an extensive education and outreach program to dispel myths about the boa and increase local peoples' knowledge of and attitudes towards snakes. Initial education and outreach programs improved students' knowledge of boas. A more extensive program was designed that aims to increase knowledge as well as improve attitudes about snakes in all sectors of Jamaican society. Jamaican boa conservation will require an integrated approach of research and education in order to target the variety sources threatening boas.

ACKNOWLEDGEMENTS

I am very grateful to have been given the opportunity to work with this incredible animal. This study would not have been possible without the dedication of WRC's field biologist, Susan Koenig, who wrote the project proposal and provided invaluable assistance in and out of the field. Financial assistance and training was provided by the U.S.D.A. Forest Service, Southern Research Station, and Jacksonville Zoo and Gardens.

Many thanks go out to my committee, Chris Servheen, Steve Siebert and Craig Rudolph for encouragement during my Peace Corps service, helping me find answers to all my programming and analysis questions and for keeping me on track as I wrote this thesis.

I could not have found dedicated and reliable local field assistants without the connections and insight of Sugar Belly. My field assistants, Marvin, Hoggy, and Damien were patient with me as I stumbled through the dense bushes and led me safely in and out of them as we tracked boas. Hoggy and Marvin also kept me company on the bike commute back and forth from my community to the research center. I am grateful to the wonderful students, Zain Mallett and Elodie Gago, who volunteered their time to conduct field work in a difficult environment.

Last, and certainly not least, I could not have gotten this far without my incredibly supportive friends and family that carried me through all the joys and struggles I experienced as a Peace Corps Volunteer. I would like to thank my mom and dad for their encouraging words and prayers and my fiancé Stephen for his love and support. Their encouragement never ceased as I readjusted to life in the U.S. and worked on this thesis.

PREFACE

This project was conducted during part of my time as a U.S. Peace Corps Volunteer in Jamaica from July 2008 through January 2010. I first met Michael Schwartz of Windsor Research Centre (WRC) during a community meeting in 2008. We struck up a conversation about my experience with telemetry, my interest in wildlife conservation and the projects taking place at the research center. Mike told me about a telemetry study the center was hoping to begin in November and I expressed my interest in learning more about the project and perhaps visiting the project site. I was able to visit WRC for the launch of the Jamaican boa project in November 2008. One thing led to another and before I knew it I was leading the field research for the project.

The Jamaican boa project was launched in November 2008 with financial assistance and training from researchers from the U.S.D.A. Forest Service, Southern Research Station, in Texas and curators from Jacksonville Zoo and Gardens (Florida). From November 2008 through mid-November 2009 I conducted field work, trained local and foreign field assistants, and gave presentations in communities and schools. With an additional grant from the U.S. Fish and Wildlife Service under the Wildlife Without Borders: Latin America and Caribbean program, this project has been extended and is being led by S. Koenig (WRC). We hope to combine results from the entirety of this study to produce publications that will aid in the conservation of the Jamaican boa and its critical habitat, Cockpit Country.

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I. INTRODUCTION

The Jamaican boa (*Epicrates subflavus*) is endemic to Jamaica and is the island's largest native predator. Known locally as the yellow boa or yellow snake, the Jamaican boa was once commonly found throughout the island (Gosse 1851). Today, boa populations are fragmented into small disjunct patches due to habitat loss, the introduction of non-native predators and toxic prey, human persecution, and illegal harvesting (Gibson 1996; NEPA 2007). The Jamaican boa is classified by the International Union for Conservation of Nature (IUCN) Red List as a "Vulnerable" species (www.iucnredlist.org), listed on CITES Appendix 1 (www.cites.org), and protected by the U.S. Endangered Species Act and the Jamaican Wildlife Protection Act (1945) and its amendments (Tolson and Henderson 1993). However, enforcement of forest and wildlife protection laws is ineffective. Despite the vulnerable status of the Jamaican boa, few studies have been conducted on the species and the majority of the literature is based on anecdotal observations, oral interviews with rural residents, or extremely brief (e.g. 3-week) field research (Grant 1940; Oliver 1982; Diesel 1992; Gibson 1996; Prior and Gibson 1997; Koenig and Schwartz 2003). Intense human persecution due to fear and the mistaken belief that boas are venomous indicates the need to convey to local people the value of boas to humans as well as to Jamaican biodiversity (Kellert 1985; Dodd 2001). Conservation of this endemic species and its habitat requires knowledge of the boa's basic ecology, particularly its movement patterns and activity ranges, as well as an end to persecution and poaching.

Species Description

The Jamaican boa, *Epicrates subflavus*, is one of nine species of the genus *Epicrates* that are endemic to the West Indies (The Nature Conservancy 2004). It was officially recognized as a distinct species from the Puerto Rican boa, *Epicrates inornatus*, in 1901 (Stejneger, 1901). The Jamaican boa commonly grows to 2 - 2.5m in length but there are unverified reports of snakes as large as 5.5m (personal communication; Oliver 1982; Schwartz and Henderson 1991; Tolson and Henderson 1993). As their name implies, Jamaican boas or yellow snakes have exceptional yellow and black coloration (Figure 1). An irregular banded pattern of black on a yellow (varying from golden-brown to pale yellow) base covers the dorsal aspect of the snake, with the posterior of the body and tail being primarily black (Stejneger 1901; Schwartz and Henderson 1991; Tolson and Henderson 1993). The ventral side of the boa is a solid pale yellow becoming solid

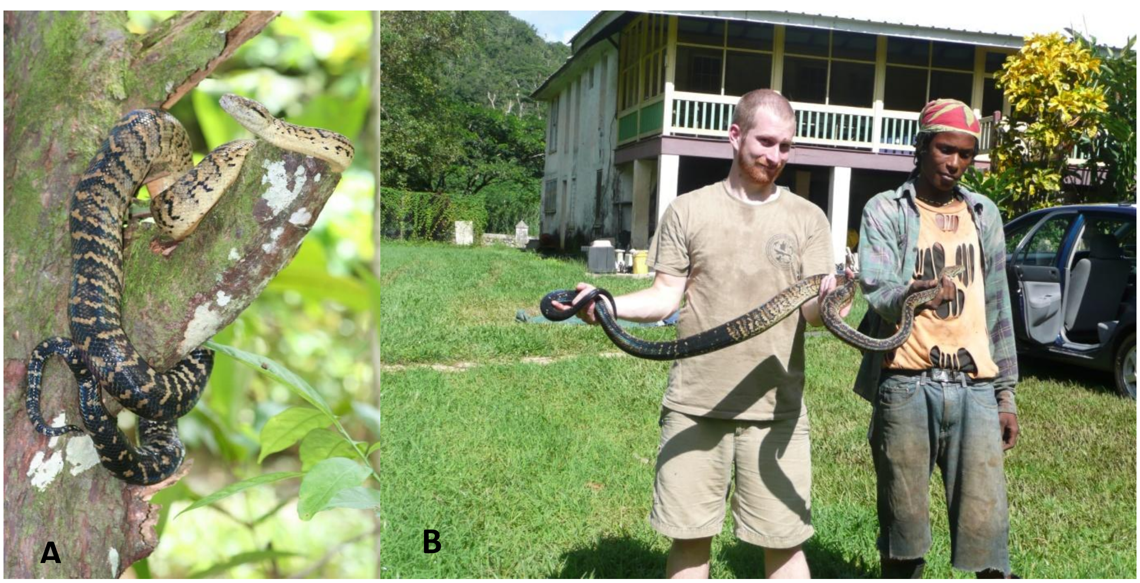

FIGURE 1. *Coloration of the Jamaican Boa, Epicrates subflavus. (A) Irregular yellow and black banded pattern with solid yellow underbelly* (c)*USFS (B) Distinct line between banded pattern and black posterior in a mature female.*

black near the tail and the snake has a black postorbital stripe on both sides of its head (Schwartz and Henderson 1991; Tolson and Henderson 1993). Females usually have more solid black coloration posteriorly than males and a more distinct line where this coloration begins (personal observation) (Figure 1a). Males can be distinguished by a set of spurs near the vent though some large females may also have small spurs (Grant 1940). The coloration becomes even more remarkable in direct sunlight as the black becomes an iridescent rainbow. The boa's cryptic coloration makes spotting them a challenge. Researchers have spent countless hours searching for boas without seeing a single one (Oliver 1982).

While boa populations were once large enough for the snake to be commonly seen throughout the island, populations are now dispersed in small patches across the island and sightings are rare (Gosse 1851, Gibson 1996). In the past 15 years, Jamaican boas have been reported in isolated areas encompassing all parishes except St. Mary and St. Andrew with the most sightings, and thus the largest suspected populations, in the Cockpit Country in central Jamaica and the Blue and John Crow mountains in the east (Figure 2) (Gibson 1996).

Little is known about the Jamaican boa's basic life history, behavior, and ecology, including movement patterns, activity ranges, and habitat use. The few observations of the boa that have been made have provided some useful information: a coarse-scale delineation of the species' distribution and the identification of critical strongholds, including Cockpit Country and the John Crow Mountains (Grant 1940, Oliver 1982, Diesel 1992, Gibson 1996, Prior and Gibson 1997, Koenig and Schwartz 2003). A recent study on the reproductive biology of Jamaica's endemic Black-billed Parrot,

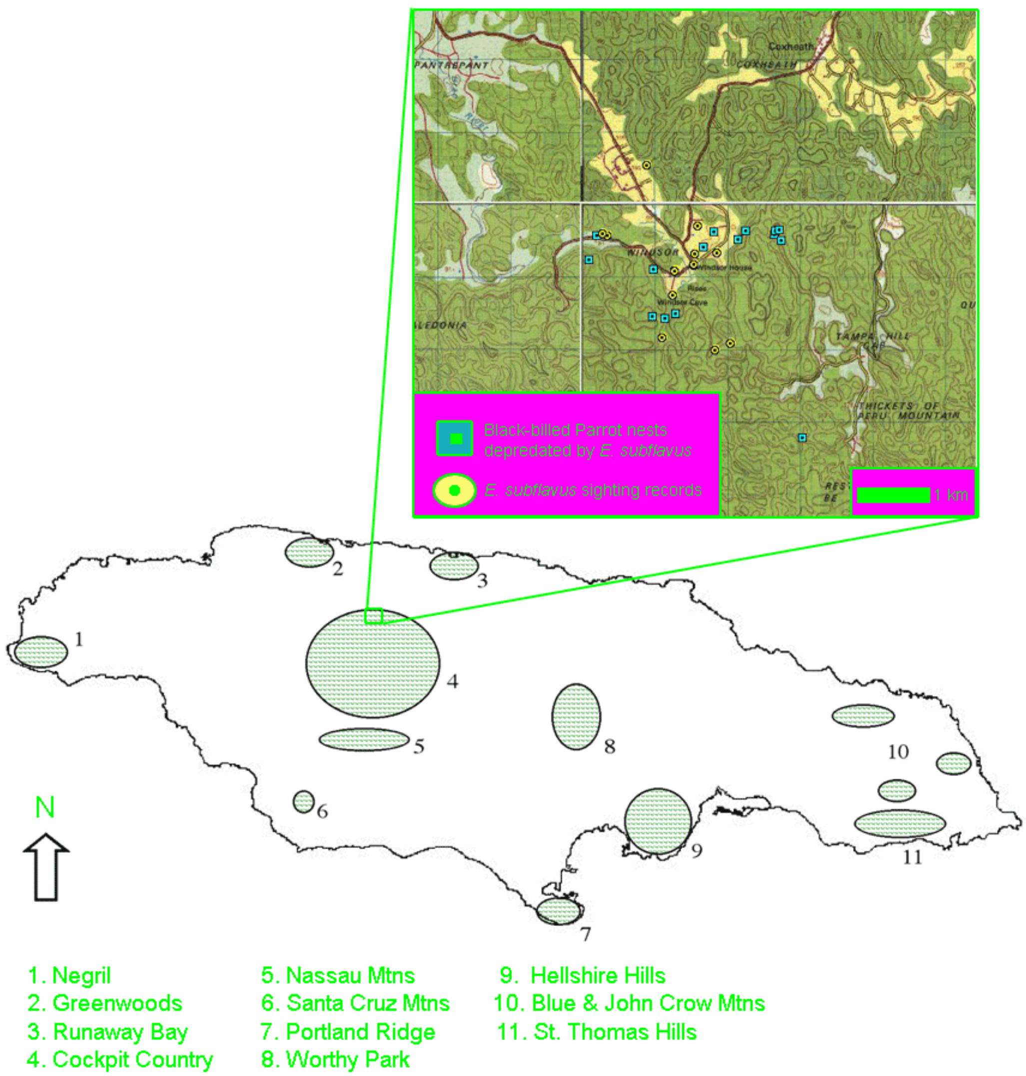

FIGURE 2. *Distribution of the Jamaican Boa Epicrates subflavus and location of telemetry study area, on the northern edge of the species' stronghold of Cockpit Country. Distribution map based on Oliver 1982 and Gibson 1996 (Koenig 2008).*

Amazona agilis, although not a study on the Jamaican boa, provided new insight into the boa's ecology:

> Parrots nesting in tree cavities in edge habitat experience rates of nestling predation more than 50% higher than those of pairs nesting in interior, core forest, with a consequence that edge habitat may represent a "sink" for the parrot population while interior is a "source" habitat (Koenig 2001). Evidence strongly suggested the primary predator of this near-threatened parrot was the vulnerable Jamaican Boa and that habitat structure mediated the dynamics of natural predator-prey interactions (Koenig *et al.* 2007). Thus, forest edges may, in turn, represent "source" habitat for the boa in terms of prey availability and accessibility, although this may be offset by increased chances of lethal encounters with humans. Similarly, if in interior forest boas numbers are in balance with parrots and other prey items (as would be predicted in an undisturbed, evolutionarily stable system), then any human activities that fragment and alter forest physiognomy could have additional consequences for predator-prey dynamics beyond a simple reduction of habitat size and species carrying capacity (Koenig 2008).

The boa is Jamaica's top native predator. The diet of the Jamaican boa has not been studied, but observations from other studies suggest that Jamaican boas are potentially an important predator of nestlings of the endemic Black-Billed Parrot, *Amazona agilis*, and the endemic Yellow-Billed Parrot, *Amazona collaria* (Cruz and Gruber 1981; Koenig 2001). Jamaican boas have also been observed catching and consuming bats at the mouths of caves (Prior and Gibson 1997; Koenig and Schwartz

2003). Although not yet confirmed, adult boas are suspected to also prey on introduced rats and juvenile boas likely consume small lizards, frogs and endotherms (Tolson and Henderson 1993).

Mating of wild Jamaican boas has not been documented but locals report the breeding season to be in March and April and parturition to occur in September and October (R. Lewis, personal communication). Captive boas have been observed mating from January until June and parturition of captive animals has occurred between September and October (Bloxam and Tonge 1981). *Epicrates* species generally reproduce biennially but one captive breeding pair reproduced 3 years in a row (Huff 1979; Bloxam and Tonge 1981). Jamaican boas are ovoviviparous with litter sizes of captive boas ranging from 3 to 39 young weighing 12.3 - 19.0 grams and measuring 36 – 53 cm total length (Tolson and Henderson 1993).

Threats

Populations of the poorly understood Jamaican boa are believed to be declining due to a variety of causes. Perhaps the greatest threat to boa populations is habitat loss (Henderson 1992). Reduction of the boas' originally widespread habitat is primarily due to agriculture, bauxite mining, and timber harvesting for boards, yam sticks, railway sleepers, and charcoal (Proctor 1986; Tolson and Henderson 1993). The amount of land used for bauxite mining tripled between 1989 and 1998 (Evelyn and Camirand 2003). Prospecting licenses in critical boa habitat threaten the Jamaican boa populations in upland, moist forest areas while in lowland coastal areas boa populations are jeopardized by conversion of habitat to hotels and tourist sites (M. Schwartz, personal communication; Henderson 1992; Tzika et al. 2008).

In addition to habitat loss, introduced species pose a threat to boa populations. The small Indian mongoose (*Herpestes javanicus*) was introduced to Jamaica in 1872 in an attempt to reduce rat (*Rattus* species) populations which were damaging the major crop of the time, sugar cane (Lewis 1949; Henderson 1992). Rather than simply eliminating rat populations, the mongoose preyed on a variety of species, bringing several native species to endangerment or extinction (Lewis 1949). Because they are nocturnal, house cats (*Felis catus*) and cane toads (*Bufo marinus*) pose much greater threats to the boa than mongoose (Henderson 1992; Tolson and Henderson 1993). Cane toads were introduced to Jamaica in 1844 in an attempt to control the rat population. These toxic toads have been found to cause mortality when ingested by boas in Puerto Rico and Jamaica (Wilson *et al. In prep.*). Since British colonization and the introduction of these non-native species, Jamaican boa populations have declined noticeably (Oliver 1982; Tolson and Henderson 1993; Gibson 1996).

Another significant threat to Jamaican boa populations is human persecution and poaching. Many Jamaicans exhibit a strong animosity towards reptiles in general and snakes in particular due to the mistaken belief that boas are venomous as well as religious associations of snakes as evil (National Environment and Planning Agency 2007). Many people also associate the term “boa” with the movie “Anaconda,” and so overestimate the size and power of the Jamaican boa (personal observation). This fear and ignorance have resulted in the common practice of killing snakes whenever they are encountered, generally by chopping them with a machete. Most Jamaicans living in or near Cockpit Country proudly state that they have seen someone kill a snake with a machete or have killed a snake themselves. Over the past few years, increasing numbers of ethnic Chinese have been moving to Jamaica to work. The Chinese bring their culture and traditions, including snake consumption, with them. The Chinese demand for snakes has increased reports of illegal harvesting from Cockpit Country (S. Koenig, personal communication). While WRC offers a small reward (US$5-10) if someone reports a snake, unverified reports claim that Chinese pay as much as US$60 per snake.

Project Significance

A greater awareness of and focus on environmental issues in the past few years has led to an increasing interest in conservation in Jamaica. This interest is reflected in several regional and area-specific plans, which list boas as important conservation targets due to habitat loss and severe human persecution: Cockpit Country Site Conservation Planning (Koenig 2002); Caribbean Eco-Regional Planning (The Nature Conservancy 2004); Draft Forest Management Plan: Cockpit Country – Martha Brae Watershed (Windsor Research Centre 2007); A Recovery Action Plan for the Jamaican Boa *Epicrates subflavus*: A look at the conservation needs of Jamaica's largest native terrestrial predator (National Environment and Planning Agency 2007). These plans all discuss the ecological importance the endemic *Epicrates* boas throughout the West Indies and the need to protect the species' native habitat to maintain viable populations of boas and their native, often endemic, prey. These papers emphasize that long-term survival of these species' will require more than just habitat protection due to the widespread persecution they face.

Movements, activity range sizes, habitat use and temperature regulation of wild snakes can now be monitored using radio telemetry (Brown *et al.* 1982; Shine and Fitzgerald 1996; Fitzgerald *et al*. 2002). Technological advances over the past 25 years have made it possible for researchers to surgically implant transmitters in snakes with minimal stress to the animal (Reinert and Cundall 1982; Weatherhead and Anderka 1985; Hardy and Greene 1999, 2000). The results from a study on the spatial ecology of Puerto Rican boas by Wunderle et al. (2004) are being used to better conserve that species. These findings and their implications for conservation and management have led Jamaica's natural resource managers to inquire about studying the Jamaican boa using radio telemetry (National Environment and Planning Agency 2007).

The goal of this study is to better understand and enhance conservation of the Jamaican boa through an integrated program of field research, capacity building of natural resource managers, and community outreach and sensitization. Objectives include: field work to document the pattern of boa movements, determine home range size, and identify the habitats used by boas within their stronghold of Cockpit Country; strengthening the capacity of Windsor Research Centre (WRC) field assistants and Jamaican natural resource managers through mentoring in the use of radio-telemetry and conducting habitat assessments; and environmental education and outreach in schools and communities to help reduce persecution of boas.

II. STUDY AREA

The island of Jamaica is located in the Greater Antilles at 18° 15’N and 77° 20’W. Jamaica is 230km long and 80km wide covering an area of 10,900km^2 and has a population of 2.8 million. The island was named after the Taino word ‘Xaymaca,’ which means ‘land of wood and water.’ Jamaica contains a variety of landscapes from lower montane rain forest and wet limestone forest to mangrove forest to cactus scrub (Aprey and Robbins 1953). Recent reported deforestation rates vary substantially from 0.03% to 6.7% with the most recent studies documenting rates of 0.1% and 1.5% (Tole 2002; Evelyn and Camirand 2003).

This study was conducted in the small community of Windsor (pop. 15), Trelawny Parish, on the northern side of Cockpit Country (18°18’ - 18°24’N; 77°35’ - 77°40’W) (Figure 2). Windsor is comprised of a mosaic of wet limestone forest and mixed agriculture (e.g. coffee, banana, sugarcane). Cockpit Country was named by 17th century British for its likeness to a cock fighting arena: conical depressions surrounded by steep-sided hills. The hills are spaced approximately 100m apart with elevations from sink to summit ranging from 50 – 100m (Lyew-Ayee 2010). The density and steepness of the hills makes for some very harsh terrain. Since karst topography defines the area there are many underground rivers, caves, and sinkholes. Three large rivers, Black River, Great River, and Martha Brae River, begin in Cockpit Country and combine with the multitude of underwater aquifers and rivers to provide 40% of the island’s fresh water (S. Koenig, personal communication). Temperatures range from the low 20s to mid 30s °C and annual rainfall varies from 190 to 380cm annually, with the interior forest receiving the greatest amount of rain (Proctor 1986). Rainfall varies seasonally; the wettest months are April - May and September – October. January and March are generally the driest months (Koenig, unpublished).

Cockpit Country is one of Jamaica's largest remaining forested areas (along with the Blue and John Crow Mountains in the east). Specific boundaries of 'Cockpit Country' are in dispute but the area covers approximately 600km^2 of which about 450km^2 are forested and 223.27km^2 are forest reserves (Newman et al. 2010). Forest cover declined at a rate of 0.2% and 0.93% per year from 1985-1989 and 2002-2008, respectively, and increased by 0.66% per year between 1989 and 2002 (Newman et al. 2010). Cockpit Country contains incredible biodiversity including 14 of Jamaica's 21 endemic frogs, 4 of which are Critically Endangered and 6 of which are Endangered; 27 of Jamaica's 28 endemic birds; over 100 species of land snails; and is one of only two sites where the endemic Endangered Giant Swallowtail Butterfly (*Pterourus homerus*) is found (Koenig 2002).   One hundred one vascular plants, mostly found on the hillsides, are endemic to Cockpit Country (Proctor 1986).

In addition to geographical and biological uniqueness, Cockpit Country also has historical significance. The area was home to a population of native islanders, known as Tainos, who lived in caves, including some caves in the Cockpit Country that still contain artifacts. When the British arrived in Jamaica in 1655 some of the freed Spanish slaves fled to the hills of Cockpit Country to escape British soldiers (see www.cockpitcountry.com). The hills served as a refuge for these people who became known as the Maroons. The Maroons and British fought the First and Second Maroon Wars in the 1730s and 1770s-1790s, respectively. The first war ended in 1738 with a treaty that gave the Maroons freedom and ownership of 1500 acres of land in Cockpit

Country (Price 1996). The Second Maroon War was focused in Trelawny Town on the western side of Cockpit Country. When this war concluded, Trelawny Town Maroons were forcefully deported to Nova Scotia then moved to Sierra Leon after many died from the foreign climate (Price 1996). Many Maroon communities persist in Cockpit Country and pride themselves in remaining true to their heritage and culture.

Windsor Research Centre (WRC) is housed in the historic Windsor Great House in the rural Windsor community. The research center was founded to fulfill the need for a research base in central Jamaica to assist researchers and students working to conserve Cockpit Country (www.cockpitcountry.com). WRC has played in integral part in the conservation and research of Cockpit Country since the mid-1990s through a combination of research and outreach to local farmers as well as pertinent government agencies. WRC offers a reward of US$5-10 for each boa reported to them and since 1999 has had reports of and/or seen over 80 individual boas. When possible, the boas are caught and marked by using either scale-clipping or Passive Integrated Transponder (PIT) tagging and then released at point-of-capture.

III. METHODS

Capture and Measurement

Twenty-two Jamaican boas (6 males, 13 females, and 3 which were too small to probe to determine sex) were captured in the Windsor area of Cockpit Country from 5 November 2008 to 10 November 2009. These boas were found through incidental sightings and reports from local people. Once a snake was caught and brought to WRC, it was weighed and measurements were taken of snout-vent length (SVL), total length (TL), tail length, head length, and head width. Snakes were sexed using cloacal probing, and all were injected with Passive Integrated Transponder (PIT) tags. Twelve boas (4 males, 8 females) were implanted with transmitters as they were captured during the study. The other 9 snakes were measured and PIT tagged but not fitted with transmitters due to small size or distance from the Windsor study site. Boas were released at point-of-capture.

Telemetry and Radio-Transmitter Implantation

All transmitter surgery and snake handling was done by Windsor Research Centre personnel using their permits and equipment. Boas were monitored using temperature sensitive transmitters (model SI-2T by Holohil Systems, Ltd, Carp, Ontario, Canada; size: 9 g, 10 x 29 mm cylinder with 28 cm whip antenna) operating at US Forest Service assigned frequencies of 150 to 152 MHz. Tracking was conducted using a handheld 2-element H-style antenna with TR 2 (Telonics) and R-1000 (Communications Specialists, Inc) receivers. Because of the 9 g weight of the transmitter and battery package only individuals of at least 100 cm snout-vent length were implanted with transmitters.

U.S. Forest Service and Windsor Research Centre personnel trained a local veterinarian in transmitter implantation procedures. The veterinarian then surgically implanted the transmitters with sterile techniques using a modification of the method developed by Reinert and Cundall (1982) and successfully used in subsequent studies (e.g., Weatherhead and Charland 1985, Ealy *et al* 2004, Wunderle *et al.* 2004). Relevant to our research, Wunderle *et al.* (2004) experienced no mortality of Puerto Rican Boas from either the anesthetic agent or surgery.

Snakes were injected intramuscularly with the anesthetic agent ketamine (Mallinckrodt) at a dosage of 70mg/kg of body weight then placed back in a holding cage. After 10-15 minutes or when movements were very minimal, the snake was removed from the cage and surgery was performed.

Transmitters were implanted subcutaneously approximately 15 cm anterior to the cloaca. A vertical incision (approximately 1cm long) was made in the skin beginning on scale row 3. A scalpel handle was then used to open a pocket (to receive the body of the transmitter) between the skin and musculature posterior to the incision. The transmitter was inserted into this pocket then a 35 cm canula was inserted into the incision and worked beneath the skin in an anterior direction. A second incision was made approximately 30 cm anterior to the first, at the end of the canula. The antenna was then fed through the canula and the canula removed through the second incision, leaving the antenna in place beneath the skin. The first incision was closed with sutures; the second was small and did not require sutures. Polysporin (antibiotic) was applied to both incisions. Snakes were kept in temperature-and light-controlled terraria to monitor for post-operative difficulties and ensure that the sutures were healing. After approximately two weeks of recovery, snakes were released at their capture locations.

Movement and Activity Range

Transmitter-equipped boas were located twice weekly by ground tracking during the day (0700 – 1600h) at 2 – 4 day intervals from date of release through 10 November 2009. Locations were determined by following the radio signal to the general area where the snake was located. Snakes were often not visible because they were either underground, inside a tree cavity, or amidst very dense understory or canopy vegetation. Due to this low visual detection of boas, trackers took bearings from several different locations, gradually circling in on a specific tree or ground location. When a snake was located on or under the ground but not visible, trackers were confident that the snake was within $2m^2$ of the recorded location. When the snake was located in a tree but not visible, trackers were confident that the snake was in the bole or canopy of that specific tree.

Once a snake was located, data on date, time, weather, snake location (tree, ground/underground, or other), visibility of the snake (visible vs. not visible), and mobility was recorded. Each location was individually numbered and flagged and geographic coordinates obtained using a Garmin GPS-76 handheld receiver with WAAS enabled. The coordinates of all snake fixes were plotted on maps using ESRI ArcGIS 9.3 software (Environmental Systems Research Institute, Inc., Redlands, CA). Locations were considered new if >5 m from the previous location.

Several movement indices were calculated following Wunderle et al. (2004). Total distance moved was found by summing the linear distance between successive location fixes. Mean daily movement per fix was calculated by dividing each linear distance between successive fixes by the number of days between the two fixes then taking the mean. Mean daily movement per move was calculated by dividing the linear distance between successive fixes in which the snake moved by the number of days between the two fixes and then taking the mean. Minimum immobility time was calculated from the mean number of days between fixes where no movement between fixes (> 5 m) was detected.

Home range, defined as the area to which an animal normally confines its movements, was described with the minimum convex polygon (MCP) method (Southwood 1966; Jennrich and Turner 1969). The MCP method was chosen because it is most commonly used throughout the relevant literature, and therefore allows comparisons to be made between studies. Home Range Tools (Rogers et al. 2005) for ArcGIS 9 (Environmental Systems Research Institute, Inc., Redlands, CA) was used to determine the size of the activity ranges (95%) and core areas of activity (50%). Home range estimations are dependent on sample sizes, with few samples often leading to underestimation of home range area (White and Garrot 1990; Girard et al. 2002). Therefore, home ranges were estimated only for the 6 individuals with at least 50 location fixes.

Vegetation and Structural Habitat Use

At each transmitter relocation fix a set of standard habitat variables were measured, centered on the location of the boa (Table 1). Some variables were collected at all fixes (e.g. slope, canopy cover) and some variables were specific to the snake location. For example, tree DBH and canopy connectivity were measured only for arboreal fixes. With the boas as the center point, variables were measured in a circular plot of 16 m diameter (0.02 ha).

Table 1. *Habitat variables collected for snake locations and random plots.*

Variable	Description	Methods
All Locations		
Slope (degrees)	Slope of the land at the vegetation plot	Clinometer
Distance to nearest canopy tree (m)	Distance from the snake tree or random tree to the nearest canopy tree	Tape measure
DBH of nearest canopy tree (cm)	DBH of the canopy tree closest to the snake tree or random tree	Tape measure
Understory vegetaion-3m radius (%)	The percent of understory vegetation covering the ground in a 3 meter radius of the snake or random location	Visual estimate
Mean % canopy cover	Average of 4 measurements taken 8m (N, S, E, W) from the center of the plot	Densiometer
Mean % soil Mean % rock Mean % litter Mean % debris Mean % water	Average of 4 estimates of ground cover taken 8m (N, S, E, W) from the center of the plot. Ground cover was divided into 4 main categories - soil, rock, leaf litter, woody debris - with water added for locations near rivers.	Visual estimate
Mean # stems <3cm DBH	Average number of vines and trees with a DBH less than 3cm along 4 8m-long transects extending from the center of the vegetation plot	A field assistant walked along each transect with arms outstretched and counted all vines and trees (<3cmDBH and at least chest height) that touched their body and arms.

# Stems >3cm	Total number of stems with DBH greater than 3cm within the 8m-radius vegetation plot	Count
Mean DBH of stems >3cm	Average DBH of all stems greater than 3cm DBH within the vegetation plot	DBH of all trees and vines (with DBH >3cm) in the 8m-radius plot were measured then averaged

Arboreal Locations

Central tree DBH (cm)	DBH of the snake tree or random tree	Tape measure
Central tree height (m)	Height of the snake tree or random tree	A clinometer was used in open areas. In areas with steep hills and dense vegetation, visual estimates were used.
Central tree height 1st branch (m)	Height of the first branch of snake tree or random tree	A tape measure was used for low branches. A clinometer or visual estimate was used for branches higher than 2m
Central tree canopy cxn (%)	Percent of the snake tree or random tree's canopy that is connected to other tree canopies	Visual estimate
Attached vine height (m)	Height of vines attached to the bole of the snake tree or random tree	A clinometer was used in open areas. In areas with steep hills and dense vegetation, visual estimates were used.
Attached vine density	Density of vines attached to the bole of the snake tree or random tree	Visual estimate using a scale of 0-3 where 0 = no vines and 3 = heavy vine density
Unattached vine height (m)	Height of vines unattached to and within 1m of the bole of the snake tree or random tree	A clinometer was used in open areas. In areas with steep hills and dense vegetation, visual estimates were used.
Unattached vine density	Density of vines unattached to and within 1m of the bole of the snake tree or random tree	Visual estimate using a scale of 0-3 where 0 = no vines and 3 = heavy vine density

Overall epiphyte density	Density of epiphytes on the snake tree or random tree	Visual estimate using a scale of 0-3 where 0 = no epiphytes and 3 = heavy epiphyte density

Terrestrial and Underground Locations

% Soil @ snake	Ground cover measured in a 1m radius of the snake or random location. Ground cover was divided into 4 categories: soil, rock, leaf litter, woody debris.	Visual estimate
% Rock @ snake		
% Leaf litter @ snake		
% Woody debris @ snake		
Understory vegetation @ snake (%)	The percent of understory vegetation covering the ground in a 1m radius of the snake or random location	Visual estimate

In addition to the habitat variables listed in Table 1, species of the snake location tree and of attached and unattached vines were recorded when known. Also, types, sizes, and numbers, of epiphytes on the tree were recorded, noting tank bromeliads, orchids, cacti, and filmy ferns.

For every boa location, the same habitat variables listed above and in Table 1 were measured at a random location. The random site was located twenty meters from the snake location in a randomly selected cardinal direction. If the snake was located in a tree, the random habitat plot was centered on a canopy tree. If the snake was located on or under the ground, the random habitat plot was centered on a point on the ground.

Data Analysis

Statistical analyses were performed using SPSS. Data were tested for normality and equality of variance using the Kolmogorov-Smirnov test and the Levene test, respectively. A one-way ANOVA was used to test parametric variables and the Mann-Whitney U test was used to test non-parametric variables. Results were considered significant when p-values were less than 0.05.

Movement indices were compared between male and female boas. Habitat characteristics of boa plots were compared with those of random plots. Habitat variables with significant differences between boa and random plots were further examined using principal component analysis (PCA). Activity ranges were not statistically analyzed due to small sample size (2 males, 4 females).

IV. RESULTS

Snake Characteristics

Radio telemetry was used to track 12 Jamaican boas (4 males, 8 females) from 27 November 2008 to 15 November 2009 (Table 1). Boas were added to the study as they were captured and brought into WRC. The last individuals that were fitted with transmitters (5F3 and 255) were released on 5 September 2009. Two individuals (4DC and AF9) died during the study period and the signal from one individual (512) disappeared.

Visuals

Visual detection of boas was very difficult due to dense vegetation in the forest and cryptic coloration of the snakes. Boas were seen at only 26.3% of the radio location sites. Males were seen at 22.4% of locations while females were seen at 27.9% of locations. This visual detection rate is higher than the 15.5% visual rate recorded by Wunderle et al (2004) for the Puerto Rican boa.

Movements

Snakes were located on average every 3.7 days (range: 0-11days). Weather conditions prevented tracking from occurring on some days, especially during the rainy season. Snakes were tracked from 61-290 days, with a range of 12-68 fixes. Several females had a low number of fixes: two individuals (4DC and AF9) died during the study period; the signal of one individual (512) disappeared; and one individual (DD8) was recaptured and held for several weeks due to transmitter complications. Since individuals

Table 2. *Characteristics of 12 Jamaican boas tracked with radio telemetry in Cockpit Country, Jamaica.*

Snake	Weight (g)	Snout-Vent Length (cm)	Release Date	# of Days Tracked	# of Fixes	Total Distance Moved (m)
Males						
475	2320	173	19-Jan-09	290	68	5569.3
9FF	2320	173	4-Mar-09	250	63	4755.0
255	1450	150	5-Sep-09	64	12	1119.8
5F3	810	112	5-Sep-09	64	13	307.2
Females						
7DC	1040	131	2-Mar-09	252	68	2516.1
E5A	1540	142	2-Mar-09	252	61	3116.2
AF9	2500	178	19-Jan-09	217	56	1873.4
78B	2500	169	11-Apr-09	209	58	2917.3
512	2400	179	29-Nov-08	131	37	874.6
E35	2050	151	4-Jul-09	129	39	495.8
DD8	990	115.5	11-Jun-09	100	24	757.9
4DC	2595	176	8-Dec-08	61	19	329.2

were added through the year-long study period, some individuals have fewer fixes (e.g. 255, 5F3).

The Kolmogorov-Smirnow and Levene tests determined that all movement indices were nonparametric. Therefore, the Mann-Whitney U test was used to compare the indices between males and females.

Male boas moved significantly farther per day between fixes than females ($p = 0.006$). Mean daily movement per fix of males was 18.60m ± 2.7SE while daily movement per fix of females averaged 10.45m ± 0.9SE.

Mean daily move per move also differed significantly between sexes ($p < 0.001$). Males moved farther per day, on average, than females (26.08m ± 3.6SE vs. 17.10m ± 1.2SE).

Mean immobility did not differ significantly between males and females ($p = 0.430$). On average, males remained in one location for 6.4 ± 1.0SE consecutive days and females remained in the same location for 6.4 ± 0.7SE consecutive days.

Activity Range

Home ranges (95% MCP) ranged from 2.24ha to 14.03ha and core activity areas (50% MCP) ranged from 0.29ha to 1.95ha. The males had much larger activity ranges (10.53ha and 14.03ha) than the females (2.24ha – 3.66ha). Males also had larger core areas (1.42ha and 1.95ha) than females (0.29ha – 0.81ha). Figure 3 illustrates two typical home ranges.

Almost all snakes (except 255, 5F3, and 512) returned to previous location fixes. Males returned to 5.8% of locations one time and 0.6% of locations three times. Females

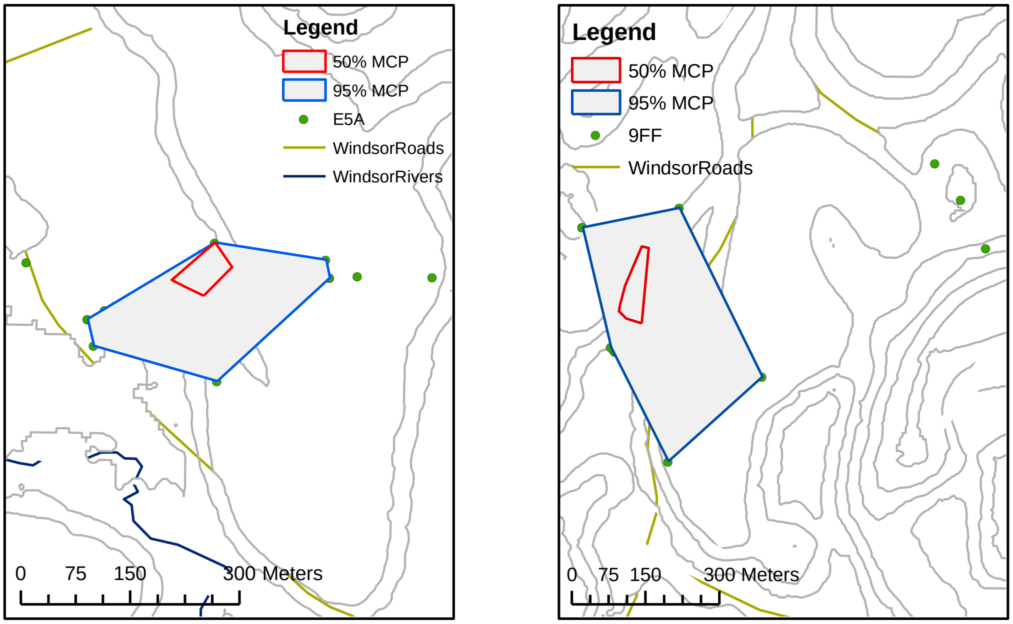

Figure 3. *Examples of 95% and 50% MCP home ranges for a) boa E5A and b) boa 9FF.*

returned to 3.9% of locations one time, 0.3% of locations two, three, and four times, and 0.6% of locations five times.

Habitat Use

Boas used both arboreal and terrestrial/underground habitats. Terrestrial and underground locations accounted for 25.7% of all fixes and arboreal locations accounted for 74.3% of fixes. Females were located in terrestrial or underground habitats for 27.7% of fixes while males were located in terrestrial or underground habitats during 19.8% of fixes. The difference between sexes was not significant.

Many different tree species were used by snakes. Most commonly used species were john crow bead (*Adenanthera pavonina*), sweetwood, breadnut (*Adenanthera pavonina*) and fig (*Ficus membranacea*). The use of all of john crow bead and breadnut trees matched with species availability in the surrounding habitat. Sweetwood trees were used half as often as expected by availability (10 snake locations vs. 19 random locations) and fig trees were used 10 times more often than they were available (20 snake locations vs. 2 random locations). Tree species used at least twice as often as availability would expect include guango (*Samanea samen*), rose apple (*Syzygium jambos*), rodwood, dogwood, bullet, and orange[1].

Twenty-seven habitat characteristics (Table 1) were compared between boa locations and random locations using Mann-Whitney U tests. Of these 27 variables, 9 variables differed significantly ($p < 0.05$) between boa and random locations (Table 3). Boa plots had a greater slope and less understory vegetation than random plots. Trees in which boas were located had larger diameters and were taller than randomly selected trees. Additionally, vines (both attached and unattached) and epiphytes were more dense on snake trees and vines (both attached and unattached) were taller on snake trees than on random trees.

Vines most commonly found attached to and unattached to (and within 1m of) snake trees were philodendron, hogmeat, snake wiss, and wicker[2]. Philodendron, snake wiss, and wicker were located on snake trees approximately twice as often as would be expected given their occurrence on random trees (124 vs. 73; 73 vs. 35; 58 vs. 28). While hogmeat was very common both attached and unattached to snake trees, it was just as common attached and unattached to random trees (110 vs. 86).

As indicated by the significant difference in overall epiphyte density, all types of epiphytes (tank bromeliad, orchid, fern, cacti, other) were more plentiful on snake trees

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[1] Tree species without scientific names have not yet been identified. Names used to identify the species are local names given by local people.

[2] Vine species have not yet been identified. Names used here are local names given by local people.

Table 3. *Results of Mann-Whitney U test for differences of means of habitat variables between snake plots and random plots.*

Habitat Variable	Boa Plot $\bar{x} \pm$ SE	Random Plot $\bar{x} \pm$ SE	P-value
Slope (degrees)	20.9 ± 1.6	15.9 ± 1.0	0.048
% Understory vegetation	27.5 ± 2.1	32.4 ± 2.2	0.020
Central tree DBH (cm)	50.6 ± 3.6	18.1 ± 1.3	< 0.001
Central tree height (m)	20.1 ± 1.0	14.3 ± 0.8	0.008
Height of vines attached to tree (m)	11.7 ± 0.7	8.8 ± 0.7	< 0.001
Density of vines attached to tree	1.3 ± 0.1	1.1 ± 0.1	< 0.001
Height of vines unattached to tree (m)	11.9 ± 0.7	7.7 ± 0.6	< 0.001
Density of vines unattached to tree	1.4 ± 0.1	1.1 ± 0.1	< 0.001
Epiphyte density on tree	0.8 ± 0.1	0.4 ± 0.1	< 0.001

than on random trees. On average, each snake tree had 7 epiphytes while each random tree had 3 epiphytes. Tank bromeliads and ferns were the most common epiphytes on all the trees. Snake trees contained 6 times more large tank bromeliads and 22 times more large cacti than random trees.

PCA analysis of the 9 significant habitat variables showed that 4 principal components accounted for 71.9% of the total variance in the habitat data (Table 4). PC1 showed that central tree DHB (cm), central tree height (m), and overall epiphyte density were strongly positively related with each other, accounting for 27.3% of the variance. The pairs of height of vines attached to the bole (m) and height of vines unattached to the bole (m) (PC2; 16.8% of variance) as well as density of vines attached to the bole and density of vines unattached the bole (PC3; 16.5% of variance) were also strongly positively correlated. Slope (degrees) and percent of understory vegetation were negatively related (PC4; 11.3% of variance).

Table 4. *Factor loadings of the first four principal components from the PCA of nine habitat variables that differ significantly between boa habitat plots and random habitat plots. Factor loadings below 0.4 have been removed to better show the strong loadings.*

	Component			
Variable	1	2	3	4
Slope (degrees)				**-0.726**
Understory vegetation-3m radius (%)				**0.781**
Central tree DBH (cm)	**0.827**			
Central tree height (m)	**0.77**			
Attached vine height (m)		**0.731**		
Attached vine density			**0.829**	
Unattached vine height (m)		**0.887**		
Unattached vine density			**0.829**	
Overall epiphyte density	**0.678**			
Eigenvalue	**2.459**	**1.512**	**1.487**	**1.013**
Percent of variance accounted for	**27.318**	**16.798**	**16.517**	**11.258**

Diet

Collection and analysis of fecal samples found the diet of the Jamaican boa to be composed primarily of rats (*Rattus* species) and also some bats and birds. From 14 fecal samples collected between November 2008 and November 2009, 10 samples contained rat remnants, 3 contained evidence of bats, and 1 sample contained feathers and a leg of a Jamaican woodpecker (*Melanerpes radiolatus*). Only one sample contained bat bones that were intact enough to identify the bat species. The forearm bones were measured and compared with the literature to identify the bat as the velvety free-tailed bat, *Molossus molossus.*

In most cases I was unable to determine if more than one individual prey item was present in any fecal sample. One exception was a fecal pellet that contained bones from at least 5 juvenile rats. Table 5 shows the contents of each fecal sample and where the

Table 5. *Contents of fecal samples from Jamaican boas captured in different habitats.*

Snake location	Prey item
Cave opening in forest	*Rattus* species
Cave opening in forest	*Molossus molossus*
Cave opening in forest	unknown bat
Cave opening in forest	unknown bat
Regenerating forest	*Rattus* species
Regenerating forest	*Rattus* species
Edge of forest, pasture, and river	*Rattus* species
Edge of forest	*Melanerpes radiolatus*
Edge of forest, yard, and agriculture	*Rattus* species
Overgrown pasture	*Rattus* species
Coffee field	*Rattus* species
Coffee field	*Rattus* species
House	*Rattus* species
Building rafters	unknown bat
Grassy yard	*Rattus* species

sample was found or the snake that produced the sample was caught. Fecal samples containing rat remains came from snakes located in all habitats while the samples containing remains of bats came from snakes captured by the opening of a bat cave.

Conservation efforts

While serving as a Peace Corps Volunteer (PCV) I initiated a Jamaican boa education program. I gave Jamaican boa presentations at schools across the island. The presentation lasted 15 minutes followed by questions. I gave a short 5-question multiple-choice assessment before and after the presentation to measure change in knowledge. Due to high illiteracy rates in earlier grades in rural areas, I only gave the assessment to grades 4 and higher. One by one, I displayed each question onto a large screen and read the question and multiple choices answers out loud. Students were given a couple minutes to reread the question and write down their answer before I moved on to the next question. The presentation included a basic description of the Jamaican boa (appearance, habitat, diet, climbing), an explanation of why the boa is important, and a brief summary of my research.

As a PCV, bringing a live snake to schools/communities in Jamaica was not feasible. I traveled around the island using public transportation, which is very cramped. I would not have been able to carry a snake in a terrarium. On one occasion, WRC brought a boa to a night-time presentation in a community with reports of poaching. This snake was being held at WRC to be implanted with a transmitter and added to the study. The snake remained in a terrarium the entire presentation and drew a lot of attention and raised many questions about snakes. Ideally we would need one snake committed to education, which we could depend on to act calmly and be handled regularly and in stressful situations. Jamaican classrooms are extremely chaotic, which could stress a wild snake. It is also difficult to control behaviors of children in Jamaica so keeping them in order and keeping them from mobbing the snake could be difficult.

Because I could not bring a live Jamaican boa to the presentations, I carried with me a realistic 6-foot long rubber snake and some real pieces of snake skin. I would pull the rubber snake out of my bag after describing what the boa looks like. The children (and teachers) typically backed as far away from me and the snake as possible and one 3rd grade class even screamed in sheer terror. After I explained that the snake was only rubber, the children would slowly calm down and by the end of the presentation most of them were anxious to touch the rubber snake. Some of the children who were the most scared in the beginning even allowed me to put the rubber snake around their neck (Figure 4).

Figure 4. *Use of a rubber snake in Jamaican boa education: children who originally screamed in fear were excited to touch the snake by the end of the presentation.*

I was able to visit 9 communities across the island. The results from the assessments were encouraging: 26.2% of students increased their score by one point; 31.6% increased two points; 17.3% increased 3 points; 5.9% increased by 4 points; 0.8% increased by all 5 possible points; and 5.1% got all the questions correct on both assessments. Although I did not quantitatively assess the younger grades (basic school – grade 3), these students' knowledge of the boa also seemed to improve. Students were attentive throughout the presentation, asked thoughtful questions, and correctly answered questions I posed to them. I also gave a few presentations at community meetings, the results of which were not evaluated. To make the education program more sustainable, I trained PCVs while visiting their communities; I provided them with the slideshow and gave them answers to commonly asked questions.

Besides the broad outreach and education described above, I trained local young men as well as member of the Forestry Department in field research methods. Over the one year that I was working in the field with WRC, I trained 6 young men from surrounding communities to become field assistants. These men learned about scientific integrity, radio telemetry, and use of a compass, clinometer, and measuring tape. While they taught me names of trees and how to navigate through the dense forest, I gave them skills that will allow them to continue working with WRC or perhaps the Forestry Department. Out of the 6 men, 2 remained as field assistants for at least 6 months. The others lost interest in the project or found the work to be more rigorous and demanding than they expected so they quit or simply stopped coming to work.

I also worked with a Forest Officer and a Forest Warden who were assigned to patrol the forest reserves in the Windsor area. Once to twice a week they came into the field with me and I trained them in habitat data collection methods. They learned skills such as creating sample plots, measuring DBH, using a compass and clinometers, and estimating canopy cover and ground substrate. They can use the skills they learned to move up within the Forestry Department. One great use of their new skills would be for them to become members of the department's forest inventory team, which collects detailed data on forest plots throughout Jamaica.

IV. DISCUSSION

Movements and Activity Ranges

Movements of Jamaican boas were similar to movements recorded for the related Puerto Rican boa (Wunderle et al. 2004). As with Jamaican boas, male Puerto Rican boas moved farther per fix and per move than females. However, immobility differed between the species. Wunderle et al. (2004) found that female Puerto Rican boas remained immobile significantly longer than males while no significant difference was found for Jamaican boas.

Stickel and Cope (1947) were the first to present evidence that snakes have home ranges and generally travel only short distances. The 95% and 50% MCPs for Jamaican boas indicate that these snakes have well-defined activity areas with males generally using larger areas than females. Home range sizes for the Jamaican boas that were sampled are smaller than those reported for the Puerto Rican boa. The median home range sizes for the Puerto Rican boa were 5.6 and 2.2ha for the 95% and 50% MCP, respectively (Wunderle et al. 2004). The median home range sizes for the Jamaican boa were 3.66 and 0.78ha for the 95% and 50% MCP, respectively. These differences may be due to the smaller sample size of the Jamaican boa study or the more limited time Jamaican boas were tracked. Wunderle et al. (2004) calculated home range sizes for 18 Puerto Rican boas with about one year of telemetry data while Jamaican boa activity ranges were calculated from 6 boas with approximately 8 months of telemetry data. Activity range was likely underestimated not only due to the use of MCPs but also because movements between the ground and canopy were not measured or taken into account (Lillywhite and Henderson 1993).

Puerto Rican boas with home ranges near caves have much smaller home ranges than Puerto Rican and Jamaican boas in other habitats (Table 6). Puente-Rolon and Bird-Pico (2004) suggest that boas living near caves have smaller home ranges due to the high prey density provided by bats living in the caves. Jamaican boas being tracked near the cave opening in Windsor had too few locations (<25) to determine accurate home ranges. However, since Jamaican boas utilize caves similarly to Puerto Rican boas (see "Diet" below) their home ranges likely follow similar patterns. I would expect that Jamaican boas living near caves will have smaller home ranges than boas living in other areas. Continued radio-telemetry of the Jamaican boas in the cave area (in progress) will allow this hypothesis to be analyzed.

Some studies suggest that greater movements and activity ranges by male snakes may be due to a search for mates during the breeding season (Gibbons and Semlitsch 2001). While Wunderle et al.'s (2004) data show evidence for this trend Gregory et al. (2001) did not find studies stating that males have greater home ranges to be credible. A more widely accepted explanation for variations in movements and activity ranges is that these variables depend on prey (availability and species) and vegetation characteristics (Lillywhite and Henderson 1993; Gregory et al. 2001).

Table 6. *Home ranges for boas in different habitats. Home ranges reported by Puente-Rolon and Bird-Pico are 100% MCP home ranges while those by Wunderle et al. and Miersma are both 95% MCP home ranges.*

Species	Habitat	Home Range (ha)	Source
E. inornatus	Cave/subtropical moist forest	0.014 - 1.838	Puente-Rolon and Bird-Pico 2004
E. inornatus	Subtropical wet forest	5.6 (median)	Wunderle et al. 2004
E. subflavus	Wet limestone forest	2.24 - 14.03	Miersma 2010

Habitat Use

Jamaican boas were located in a wide variety of habitats that reflected the habitat types available. This finding aligns with those of Wunderle et al. (2004) as well as Tolson and Henderson's (1993) observations on all Caribbean *Epicrates*. Regenerating wet limestone forest was most frequently used but agriculture and edge habitats were also commonly used. One study individual spent a lot of time in a rural, uninhabited home and outhouse. Two other snakes not included in the telemetry study were captured in the roof and rafters of other buildings. Snakes are likely attracted to agricultural areas and buildings due to high populations of rats and bats, which compose a major part of their diet.

Jamaican boas spend most of their time in arboreal locations rather than terrestrial or underground. Puerto Rican boas exhibit the same behavior, with both males and females spending more time in trees than on the ground (Wunderle et al. 2004). Wunderle et al. (2004) also detected that female Puerto Rican boas spent significantly more time in terrestrial or underground locations than males. No significance was detected between sexes of Jamaican boas, however, the sample size was small so difference may become apparent with more data.

Tree DBH, vine coverage, and epiphyte density on the tree were the habitat features that varied most from snake plots to random plots. Greater vine height and density allow boas to move between forest levels as well as through the canopy. Vines also provide stable resting places and excellent cover. Epiphytes also provide a stable place to rest (Figure 5). Epiphytes, particularly tank bromeliads, may also be an

Figure 5. *Jamaican boas were frequently seen resting in arboreal and terrestrial tank bromeliads and on vines in tree canopies.*

important source of water and prey. Due to the limestone substrate, standing water is a rare occurrence is Cockpit Country. Between rainfalls, especially during the dry season in January to March, water that has collected between the leaves of bromeliads may be the only water available. The water source not only attracts snakes but also birds and amphibians that the snakes may prey upon.

Habitat characteristics, such as canopy connectivity and high density of vines and epiphytes, allow for movement among trees and between the ground and have been shown to be important for many arboreal snake species (e.g. Chandler and Tolson 1990; Shine and Fitzgerald 1996; Fitzgerald et al. 2002; Wunderle et al. 2004). The Virgin Islands boa, *Epicrates monensis,* favors habitat that combines high prey populations and a physical structure that allows the boa to easily move throughout the area (Tolson 1988; Chandler and Tolson 1990). In the case of *E. monensis*, closed canopies with interlocking branches seemed to be most important habitat attribute for boa movement (Chandler and Tolson 1990).

Other habitat variables that were significantly different between boa and random plots were slope, understory vegetation cover, and tree height. Tree height, DBH, and epiphyte density were strongly positively correlated. This makes sense as trees that have a larger DBH should be taller. Size of a tree is a general indication of age so the fact that larger (thus older) trees have more epiphytes, which can take a long time to establish, is not surprising. Trees used by Puerto Rican boas also had significantly larger DBHs and heights than random trees (Wunderle et al. 2004). Large trees may be preferentially used by boas because they tend to have more vines and epiphytes, which the snakes can use to rest, travel, hunt, and camouflage themselves.

Analysis showed that areas used by Jamaican boas had less understory vegetation than random areas. This is most likely due to the fact that the areas used by boas also had greater slopes than random areas. Understory vegetation may have a more difficult time growing on steeper slopes as opposed to flatter areas. Wunderle et al. (2004) found the opposite trend: sites used by Puerto Rican boas had greater understory vegetation than random sites. Puerto Rican boa sites also had more canopy connectivity, less canopy cover, and were closer to other trees compared to the random sites (Wunderle et al. 2004). These habitat characteristics were not found to be significantly different in the Jamaican boa study.

While there are differences between habitat characteristics used by the Puerto Rican and Jamaican boas, vine coverage was very important to both species. As discussed above, vines provide transportation routes as well as several other functions. Vines should be considered one of the most important habitat features to maintain in boa habitats in order to conserve these snakes.

Diet

Jamaican boas feed on a variety of prey, including rats, bats, and birds. These observations align with others' observations of Caribbean *Epicrates* (Tolson and Henderson 1993). As has been proven for other *Epicrates*, the diet of Jamaican boas likely changes from small prey, such as *Anolis* lizards, when the boas are small to larger prey like birds and rats as the boa becomes larger (Henderson et al. 1987; Tolson and Henderson 1993). Many *Epicrates* species prey heavily on *Anolis* lizards, implying that Jamaican boas also depend on these small lizards at some stage of their life (Reagan 1984; Tolson 1988; Chandler and Tolson 1990; Tolson and Henderson 1993) Henderson et al. (1987) found a distinct variation in diet between three size classes (<60cm SVL, 60-80cm SVL, >80cm SVL) of Hatian boas, *E. striatus*. The smallest boas primarily consumed *Anolis* species, the middle size class consumed *Anolis* species as well as small rodents, and the largest boas preyed on rats and birds (Henderson et al. 1987). While we did not capture any boas less then 80cm SVL, all of the boas we captured that were less than 100cm SVL came from cave openings. This suggests that bats are an important food source for large Jamaican boas (>80cm SVL) and possibly mid-sized boas (60-80cm SVL) as well.

My observation of bats as an important prey item for boas living near caves coincides with previous observations of the Jamaican boa (Prior and Gibson 1997; Koenig and Schwartz 2003) and other Caribbean *Epicrates*, including the Cuban boa (Hardy 1957) and the Puerto Rican boa (Rodriguez and Reagan 1984; Rodriguez-Duran 1996; Puente-Rolon and Bird-Pico 2004). Jamaican boas utilize the same bat-hunting technique as Puerto Rican boas. These boas use some sort of support inside the cave or at the mouth of the cave to hang vertically and strike at bats during their emergence at dusk (Puente-Rolon and Bird-Pico 2004).

Conservation: Past and Present Efforts

Research, by itself, will not have any impact on Jamaican boa conservation. To be effective, research results must be disseminated to the people who are responsible for the persecution of snakes and habitat conversion. Many of the threats to boa populations (e.g. habitat loss, persecution) could be reduced through increased knowledge and improved attitudes towards the boa. For this reason, an education and outreach program could play a major role in Jamaican boa conservation (Dodd 1993; Morton and Murphy 1995). The educational outreach program aims to reduce habitat loss, human persecution, and poaching. The focus of a boa outreach program should also focus on dispelling myths and explaining the importance of boas to the forest as well as to humans.

Existing Jamaican boa educational resources are scarce. NEPA has a series of posters on threatened and endangered Jamaican animals and one of these posters covers the Jamaican boa. Another poster was created by a collaboration of Durrell Wildlife Trust (UK), Jacksonville Zoo and Gardens (USA) and NJCA (JA). This poster contains more information than NEPA's poster but is also wordy and the color scheme makes it difficult to read. One of the key features of outreach tactics such as signs and posters is to keep them simple so that a passerby can understand the message in the few seconds they will take to look at the sign or poster (Dodd 1993). WRC is in the process of making a documentary on Cockpit Country. They plan to include some live footage and discussion on the importance of the Jamaican boa to Cockpit Country. Videos have been a part of many successful environmental education programs (e.g. Morton and Murphy 1995; Daltry et al. 2001; Seymour 2004) as they are easily distributed, require no training, and can be broadcast to large audiences.

My education, outreach, and mentoring contributed in some small yet important ways to Jamaican boa conservation. The improvement in quiz scores suggests that the children who viewed the presentation were more knowledgeable about boas after the presentation than before. Their change in attitude from fear to intrigue of the rubber snake implies an improvement of their attitudes towards snakes. The presentations were limited to schools with projectors since the presentation was PowerPoint based. I attempted to present to two classes without the PowerPoint but it was difficult to hold the students' attention and challenging for them to fully imagine what Jamaican boas look like. In the future, this difficulty could be overcome by bringing large photographs or posters with images of boas.

The fact that the local field assistants I trained were freely and regularly talking with farmers and friends about boas and preventing boas from being killed suggests that the training was successful. Not only did training these local young men provide them with an income, it also increased their knowledge and improved their attitudes about snakes. These young men will likely continue to share their knowledge and help prevent persecution of boas long into the future.

At least two snakes were not killed by farmers due to the presence of the research field team and casual conversations we had with farmers. Both boas were study animals. One was seen on the edge of a small agricultural plot while the farmers were working. The farmers had seen my field assistant and me tracking snakes in the area the previous day. When they saw the boa moving along the edge of their field they left it alone and reported it to my field assistant. Coffee reapers discovered the other boa in the canopy of a coffee tree while they were harvesting. The field team was nearby when the snake was discovered and one of the local field assistants convinced the reapers not to kill the snake.

Conservation: Future education and outreach

An effective boa conservation plan requires not only research but also education of local people about snakes, particularly their importance to humans (Kellert 1985; Dodd 2001). The educational program should reach people across all sectors of Jamaican society: adults as well as children and local communities as well as government organizations. Children are an ideal target audience to begin with because they are more open to new ideas while adults may have ingrained preconceptions about snakes (Dodd 1993; Cunningham et al. 1995). Adults need to be targeted as well, however, because by the time the current generation of children reaches adulthood the boas may already be gone (Dodd 1993).

For success and sustainability of the Jamaican boa outreach and education project (JBOE), collaboration with stakeholders island-wide will be necessary.   Figure 6 illustrates the location of potential collaborating agencies:

- Windsor Research Centre (WRC)
- Northern Jamaica Conservation Association (NJCA)
- Hope Zoo
- The National Environment and Planning Agency (NEPA),
- Portland Environment Protection Association (PEPA),
- Negril Environmental Protection Trust (NEPT)
- Jamaica Environment Trust (JET)
- Southern Trelawny Environmental Agency (STEA)
- Forestry Department
- The Nature Conservancy (TNC)

Figure 6. *Locations of potential BOE collaborators in relation to Jamaican boa distribution (green ovals). Distribution map based on Oliver 1982 and Gibson 1996.*

Four of the most stable of these organizations (WRC, NJCA, Hope Zoo, JET) could form central points for the education program. Windsor Research Centre could be the project base since the data collection is centered in the Windsor area and WRC is centrally located within Cockpit Country, the boa's stronghold. WRC will be able to reach local farmers and charcoal producers who are threats to the snakes and their habitat. WRC also has a small amount of grant money designated for education materials on the Jamaican boa. They can use these funds to begin to create resources (e.g. posters, press releases) that can be distributed and/or reproduced island wide.

Northern Jamaica Conservation Association is a non-profit NGO based in Runaway Bay, St. Ann Parish, on the north coast (www.sites.google.com/site/njcajamaica/). They have produced many environmental education resources and conducted teachers' training workshops. In addition NJCA runs the volunteer-based Seven Oaks Sanctuary for Wildlife (SOS), a non-profit wildlife rescue and rehabilitation center (www.sites.google.com/site/soswildlifejamaica/). SOS has worked extensively with Jamaican boas. The sanctuary has rescued boas from urban areas and mining sites and relocated them to forested areas. They have also nursed injured boas that had been chopped by machetes back to health. SOS cares for a couple permanent boa residents – boas that were too badly injured to be returned to the wild. These snakes have great potential for becoming education animals. Using these snakes in educational presentations would allow audience members not only to see and potentially handle a live Jamaican boa, but the snake's scars would also emphasize the effects of human persecution on these animals.

Hope Zoo, located in the capital city of Kingston on the Southeast coast, has several Jamaican boas on display. The zoo is often the only place where children get to see live boas and it is not an experience they quickly forget. Therefore, the zoo has incredible potential as an outreach center for the urban areas.

Jamaica Environment Trust is a non-profit NGO dedicated to improving environmental education in Jamaica. One of the goals of JET is "to develop and implement effective public education and advocacy campaigns to protect specific natural resources" (www.jamentrust.org). The Jamaican boa project would fit perfectly into JET's mission and goals. Because JET has a nationwide network of school programs (Schools' Environment Programme), Jamaican boa conservation could be easily integrated into school curriculums across the island.

The remaining organizations and agencies can serve as material distribution points, training centers, and sources of information. For example, one task of Forest Officers is to visit schools and give presentations on forests. When they hand out forestry resources to teachers, they could also hand out posters and information about Jamaican boas and direct the teachers to one of the central organizations, such as JET, if they are interested in participating in JBOE.

The first step in creating a successful boa outreach and education program is to determine what different target audiences (children, communities, government) know about the Jamaican boa and their feelings toward the boa (Kellert 1985). A formal assessment of this sort has not been performed in Jamaica. However, from conversations with local people, it is very clear that most Jamaicans do not like snakes. This fear and dislike is due, in part, to ignorance of the boa's role in the ecosystem and the mistaken belief that boas are venomous (NEPA 2007).

Widespread animosity towards reptiles poses a challenge to conservationists. Biologists and educators must develop a program that will help people relate to an unlikeable animal. Bat Conservation International (BCI) is one organization that faced this challenge head-on. Bats, like snakes, are often misunderstood and disliked. BCI developed an education program aimed at informing and dispelling myths to help conserve bat species around the world. The organization focused on reaching children but also made efforts to reach broader audiences, creating classroom materials, activity books, audiovisual programs, printed materials, and photo collections (Morton and Murphy 1995). Several of BCI's international programs have produced dramatic results, such as formation of protected areas and cessation of bat poisoning as well as killing bats for sport (Morton and Murphy 1995).

Similarly, biologists in the Lake Erie region (Ohio, USA to Ontario, Canada) were faced with declining populations of the endemic Endangered Lake Erie watersnake, *Nerodia sipedon insularum* due to human persecution (Seymour 2004). Lakeside residents and visitors were killing the harmless snake because of the common fear of snakes and misconception that they were venomous. In response, the U.S. Fish and Wildlife Service began an extensive education campaign that included signs, newsletters, press releases, school essay and poster contests, and public presentations (Seymour 2004). Decreased reports of intentional snake killings and increasing snake populations indicate that the program has been successful (Seymour 2004).

Conservation of Jamaican boas will require not only an increase in knowledge but also an improved attitude towards snakes (Dodd 1993). Morgan and Gramman (1989) conducted a study to determine the most effective education techniques to reach this goal. They compared the effects of 4 education techniques on students in grades 5-8. The techniques they evaluated were: 1) no interaction – no snakes were present in the room; 2) mere exposure – students simply viewed a live snake in a terrarium; 3) mere exposure plus modeling – students viewed a snake then watched an adult handle the snake; 4) mere exposure, modeling, and direct contact – students viewed a snake, saw an adult handle the snake, then touched the snake (Morgan and Gramman 1989). For each technique, one group of students was also shown a slide show while another was not. Morgan and Gramman determined that the most effective way of increasing knowledge and improving attitude about snakes was to combine the slide show with modeling or direct contact (Morgan and Gramman 1989).

JBOE could replicate the exposure plus modeling or handling and include an informational presentation. SOS-Wildlife and Hope Zoo are the only organizations that will be able to use a live snake for presentations, as they are the only ones with permanent snake residents. WRC may occasionally have a boa in holding which they can use for a presentation but often they do not keep animals for more than a couple weeks before releasing them back into the wild. SOS-Wildlife and Hope Zoo could do presentations, seminars, and trainings with live Jamaican boas at their organizations or in local area schools.

Another technique that could be very successful in Jamaica is to conduct school competitions similar to the ones hosted by U.S. Forest Service to conserve the Lake Erie watersnake (Seymour 2004). Jamaican children thrive off competition and love to receive certificates. An island-wide poster and essay competition on a topic such as "Save our Snakes" would help increase the interest of children and teachers in the topic. JET's Schools' Environment Programme would be one way to spread word of the contest to many schools.

Educational outreach can and should extend beyond classroom situations. The general public will likely not have the time or interest to go to a seminar or training session. In addition to presentations, successful conservation programs have used a variety of other outreach techniques, including posters, videos, and press releases (e.g. Morton and Murphy 1995; Seymour 2004). These strategies were all undertaken to conserve the endemic endangered Antiguan racer, *Alsophis antigue*, and a positive change in awareness and attitudes toward the snake was seen in the five years of the program (Daltry et al. 2001). Daltry et al (2001) have taken additional measures the Jamaican boa project has not yet implemented, such as television documentaries, magazine and newspaper articles, and tour operator training workshops.

The role of the media should not be underestimated. Mass media is one of the most effective and efficient ways to disseminate information to a large audience, gain support for conservation, and increase funding opportunities (Jukofsky and Wille 1995). The media plays a large role in the everyday life of most Jamaicans. You can hardly walk past a house or car that does not have a radio blaring. Radio interviews and newspaper articles would reach large audiences. The Cockpit Country documentary that is in progress will be another way to reach people through the mass media.

Conservation: Combating poaching

To combat illegal harvesting of Jamaican boas, laws must be enforced, the demand for snakes must be eliminated, or alternative economic incentives must be provided to poachers. While Jamaican boas are protected both nationally and internationally (CITES Appendix 1, Wildlife Protection Act, U.S. Endangered Species Act), enforcement is weak. As in many areas of the world, the probability of increasing enforcement is low to due lack of interest in boas, lack of political will, and lack of resources (Dodd 1993). Interest in boa conservation may be increased through JBOE but resource availability likely will not increase.

Local people in Cockpit Country are collecting Jamaican boas to sell to Chinese business owners in Falmouth who are consuming the snakes (Anonymous, personal communication). The Wildlife Protection Act (1945) and Amendment (1998) state that the penalty for hunting or possessing all or part of a protected animal is J$100,000 (US$1250) and/or one year imprisonment. However, these laws are poorly enforced. One strategy to reduce boa demand is to educate the Chinese population about the ecological importance of the boa and the laws that protect the species. WRC has some grant funds dedicated to producing pamphlets, in Chinese characters, containing this information. The Cockpit Country documentary containing Jamaican boa footage could be another useful tool in educating Chinese and reducing their boa consumption.

Perhaps the most promising approach to reducing illegal Jamaican boa harvest is to provide alternative income for poachers. Chinese have been reported to pay up to US$60 per Jamaican boa while WRC offers only US$5-10 when a Jamaican boa is turned in alive. If an alternative to selling snakes that provided greater economic returns was made available, poachers may become involved.

As an alternative source of income the young men who are collecting boas could be trained to lead tours through the Cockpit Country. Parts of Cockpit Country are located only an hour or so from major tourist cities so tourists could easily travel in for a morning or afternoon hiking tour.   Properly trained locals could not only educate and accompany tourists but also entertain them and give them a taste of Jamaican culture while they themselves are becoming more environmentally conscious (Paaby and Clark 1995).

Several tour guide training courses were held in Costa Rica with all participants gaining skills to work in a variety of conservation fields (Paaby and Clark 1995). A similar course could be conducted to train Cockpit Country tour guides. The key differences between the Latin American courses and the potential Jamaican course are literacy and language. Literacy in rural Costa Rica is very high so program directors were able to require that all participants could read and write. According the World Fact Book, literacy rates in Jamaica are 84.1% for males and 91.6% for females (www.cia.gov). This figure is deceptive because literacy was defined as “age 15 and over and has ever attended school” (www.cia.gov). Many rural Jamaicans, especially boys, progress through many grades of school without ever being able to read or write (personal observation). Therefore, a training program in Jamaica that targets poachers would not be able to require literacy; the program would have to use more visual and hands-on teaching strategies to effectively train rural Jamaicans. The second difference between the Costa Rican experience and the Jamaican is language: Costa Ricans had to be trained in the English language while the majority of Jamaicans can already understand and communicate in English. This difference makes the tour guide training simpler than in many other developing countries since language training would not have to be provided.

Another potential way to provide at least a few local residents with alternative income is to train them as field assistants. Locals are ideal field assistants, as they are ideal tour guides, because they are familiar with the area and the local flora and fauna, used to field conditions, and able to relate to local people (Madrid et al. 1995). WRC has hired young men from Windsor and surrounding communities as field assistants for the past 10 years. Once a motivated young person has been recruited, they are often eager to learn and tell their friends about the work. Jamaican field assistants working on the boa project prevented the killing of at least 2 boas by local farmers. If more locals were to work in wildlife conservation and see the value of wildlife face-to-face, persecution and poaching would likely be reduced.

Management Implications

The findings outlined in this paper on the movement and habitat use of the Jamaican boa can help shape the conservation and management of boas as well as other Cockpit Country species. The preferential use of trees covered with and surrounded by many vines and epiphytes supports Koenig et al.'s (1999, 2001, 2007) inference that parrots nesting in trees with these characteristics are more vulnerable to predation. As suggested by Koenig et al. (2007) reducing vine connection to parrot nesting trees will help reduce boa predation on nestlings.

Encroaching agriculture, bauxite mining, and timber harvesting will negatively impact boa habitat through complete destruction (bauxite mining) as well as destruction of key habitat components (timber harvesting). Vines and epiphytes have been shown to be the most important habitat features for Jamaican boas. Even less destructive forest disturbances, such as selective logging, results in the loss of these key features. Loggers often cut down not only the trees they intend to harvest but also vines and understory vegetation in order to clear paths to carry the wood out of the forest. Loss of these snake highways will make hunting more difficult for the boas as they will not be able to reach bird nests, rats, bats, etc. as easily or even at all.

Boas are habitat generalists, able to use a variety of habitat types, including agriculture and edges. As human encroachment pushes the edge of the forests farther back, boas will likely spend more time on the forest edges and in rural communities and agricultural fields. Boas are not in danger of starving due to their high consumption of rats. However, if they begin to use edges and rural land more frequently, the chance of human encounter and persecution increases.

The key to boa conservation requires reducing both habitat loss and human persecution. Reducing habitat loss will preserve more of the boas' forest habitat and allow greater access to traditional prey, such as bats and birds, as well as natural basking and rest sites, such as vines, trees, and cavities. Not all boas will remain deep in the forest interior however. As this study showed, many boas use edge and agricultural areas as well. The boas are likely drawn to these areas due to high rat populations. To protect these snakes, an education program like the one described above (JBOE) should be implemented to increase awareness about snakes and improve the attitudes of local people.

We now know more about the basic ecology of the Jamaican boa but a lot of questions remain unanswered. On a couple of occasions individuals from this study traveled up to a kilometer then returned to an exact location they had been to previously. The way in which boas are able to navigate through the dense, complex forest remains unknown. Resources limited the extent of this study to boas located within a 45-minute hike of Windsor Research Centre. Another question that remains to be answered is how the habitat use of boas in the interior of the Cockpit Country varies from the habitat use of boas on the periphery of the area.

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